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Maize growth and development thermally affected by plastic mulches

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सार – मकई के विकास और वृद्धि पर मल्च के प्रभाव की जांच की गई और वनस्पति तथा जनन अवस्थाओं के तापमान की प्रासंगिता की जाँच की गई। तापन मल्चों से गति बढ़ती है और शीतलन मल्चों में रोपण आविर्भाव तथा पर्ण आभास एवं वृद्धि धीमी गति से होती है, पर्ण क्षेत्र अपेक्षाकृत बड़ा होता है और शुष्क मल्च वाली मिट्टी में फसल सामान्यतः पहले से और अधिक होती है।

ABSTRACT. The mulch effect on maize development and grcwth is examined and the relevance of temperature to vegetative and reproductive stages is examined. Warming mulches accelerate and cooling mulches slow seedling emergence and leaf appearance and growth. Seedling establishment is more successful, leaf area is greater and yield is generally earlier and higher over warm mulched soil.

1. Introduction

The progress of a crop plant from germination to maturity depends on the interplay of genetic and environmental factors which determine the timing and rate of development. Among the environmental factors temperature is probably the most important.

In cereals, the rates of water imbibition by seeds, the water contents required for initial growth of a radicle and a shoot, and the rates of radicle and shoot elongation are all functions of soil temperature (Chaudhary *et al.* 1971, Blacklow 1971) when moisture is not a limiting factor (Ketcheson 1970, Singh and Dhaliwal 1972).

Also, the number of ear shoots (Lal 1974) and the leaf number (Coligado and Brown 1975) are determined during the very early vegetative stage, when the shoot meristem is still below or close to the soil surface following the temperature of the root medium (Beauchamp and Torrance 1969, Watts 1971). Later, leaf and tassel initiation and appearance enhance (Hunter *et al.* 1974, Coligado and Brown 1975, Beauchamp and Lathwell 1967) and time to maturity shortens with increasing air temperature. However, time to maturity may even be affected by soil temperatures experienced at the beginning of plants life (Wang 1958, Adams 1970). Thus, soil conditions during this stage are decisive for the potential of a crop like maize, whereas development rates are influenced mainly by the weather prevailing thereafter.

Therefore, mulches, by modifying soil thermal regime as well as above ground temperatures (Suzuki *et al.* 1982, Karadan and Rao 1983; Liakatas *et al.* 1986), may affect plant growth and development rates and crop production. This requires further investigation.

2. Materials and methods

Physical environment as well as biological measurements were made at Sutton Bonington, Midlands, England, during a maize growing period.

A range of microclimates was induced by black (BL), aluminized (AL)and clear (CL) plastic mulches, whereas bare soil (BS) served as reference. Twenty four experimental plots, each 2.0 m × 1.5 m, allowed for four surface treatments and five sowings, every ten days starting on 25 April 1977, *plus* a non-sown plot. Maize seeds (cv. Salute) were drilled to 6 cm depth through slits on the films made at 0.25 m × 0.25 m intervals. The mulches were laid down when the soil was estimated to be at field capacity and water losses during development were replaced by applying irrigation under the films or above ground.

On 21 June, when emergence from the latest plots had been completed, two thirds of the maize seedlings were removed, to provide a harvest to measure establishment. Statistical analysis of variation in emergence and dry matter production was allowed by five black replicate plots prepared and sown with the same procedure on 24 June and harvested 40 days later.

To study developmental timing in relation to the calendar, phenological observations were made daily. The appearance of the coleoptile tip above ground was recorded as emergence. Leaf stages were defined by the appearance of leaf tips from the whorl of the previously formed leaves. Emergence of the staminate tassel from

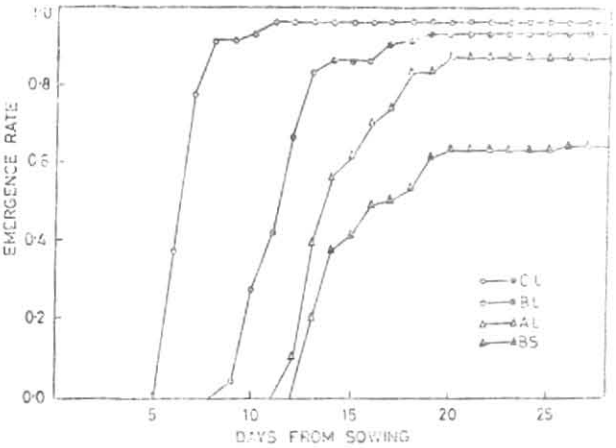

Fig. 1. Emergence rate of seedlings from the third sowing on the CL, BL, AL and BS plots, against time from sowing

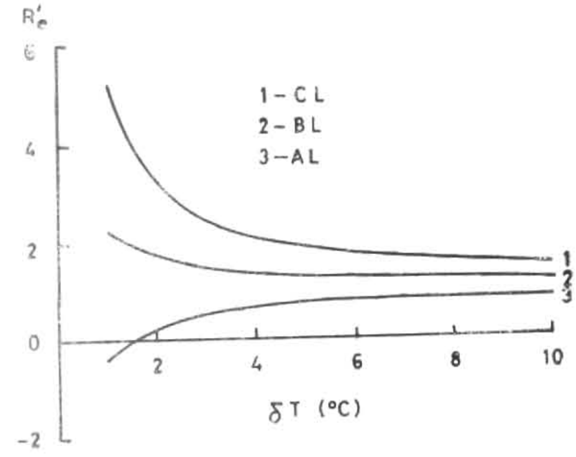

Fig. 2. Growth rate on (1) CL, (2) BL, and (3) AL plots relative to the rate on bare soil (R'_e), against 2 cm bare soil temperature above a temperature threshold (δT)

the sheath of the top leaf and appearance of the silks through the tips of the ear husts indicated tasseling and earing respectively, whereas ripening of the cobs was considered to have occurred when the grain was at the milk stage. Cobs were harvested when ripe, or at the end of October/beginning of November, since there was a considerable risk of air frost (1 out of 10 days) in November. The day of a specific stage of development was recorded as the day on which half the plants on the plot had reached that stage.

Leaf extension was measured with adjustable auxanometers (Gallagher *et al.* 1977), reset every 8-10 cm of elongation and usually after the emergence of the next leaf of representative, middle row plants. Leaf area indices (LAI) were estimated by appliation of the Duncan and Hesketh's (1968) formula to the measurements of total leaf area per plant, approximately every five days. Green leaf area of tillers, as contributing to the plants photosynthetic ability, was also included. Fresh and dry matter of above ground plant parts were measured at thinning and at maturity.

Soil, plant meristem and in-canopy temperatures were measured with diode or copper-constantan thermocouple thermometers, accordingly. Temperature and leaf extension were recorded every ten minutes using a data logger.

3. Seedling emergence and establishment

Typical progress and success of emergence is shown for all surface treatments in Fig. 1. The emergence period was shorter on CL and longer on AL plots, consistent with soil temperature at sowing depth. Emergence was faster and completion was earlier from all mulched plots than from the bare soil. Finally, only two thirds of the seeds sown on bare soil gave seedlings, whereas emergence on the covered plots much exceeded 80%, approximately the potential for a normal stand (Alessi and Power 1971). BS poor performance, compared even with the rather cooler AL plots, was probably due to excessive or limited soil moisture and changes in compaction.

The dry matter production, made it clear that the crops on the warmer plots were better established. The CL plots were the best. The BL plots performed consistently better than the control plots and establishment on the aluminium ones was the worst (Table I). Other workers (Adams 1970, Ketcheson 1970, Fairbourn 1974, Phipps and Cochrane 1975) have also shown better growth or high dry matter production on warmer mulched plots.

Differences between mulcheswere more pronounced for the early than the late sowings, implying that low temperatures produce greater relative differences between surface treatments. As the 2 cm depth soil temperature (approximately meristem temperature) differences between mulched plots and the control during the sowing period (23 April-28 May) were —1.4°C, 1.2°C and 4.2°C for AL, BL and CL respectively, growth and differentiation of the mulched plots would be increasingly higher (CL, BL) or lower (AL) with temperature decrease (Fig. 2). Thus small changes in soil temperatures in spring, when temperatures are low, may yield considerable performance differences between plots. Increases of growth rates in maize seedlings of as much as 30-40% per degree of soil temperature difference were also reported by Walker (1969).

4. Vegetative development and growth

Fig. 3 shows the vegetative development of the earliest sown plants in terms of time of appearance of each leaf after the second, in relation to air temperature averaged at 10-day intervals. The time intervals required to reach specific leaf stages increased with decreasing temperature. Earliness differences between treatments increased gradually and became maximum at about the seventh leaf, due to different soil temperature regimes created by the mulches. In comparison with the control, the warmer soil under the transparent (CL) and the

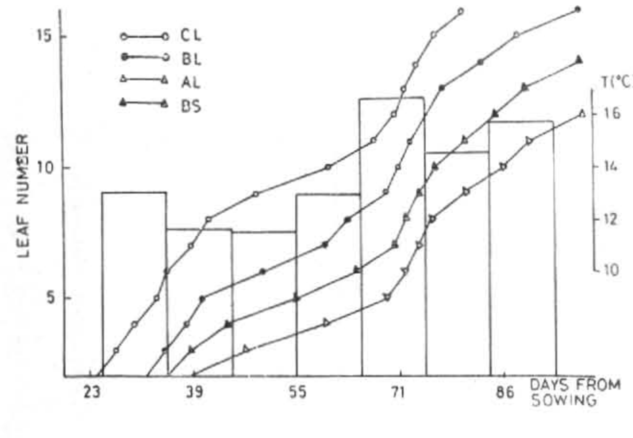

Fig. 3. Progress of leaf appearance on plants from the first sowing on CL, BL, AL and BS plots, in relation to air temperature averaged at 10-day intervals

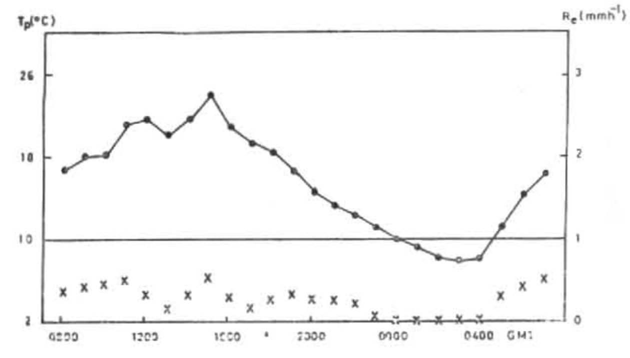

Fig. 4. Variation of leaf extension rate R_e (x — x) and plant meristem temperature T_p (.—.), on 8 June, 1977

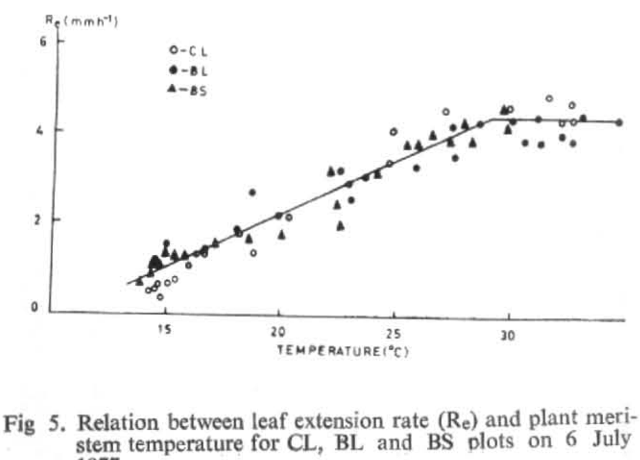

Fig 5. Relation between leaf extension rate (R_e) and plant meristem temperature for CL, BL and BS plots on 6 July 1977

TABLE 1

Development progress and average yields

Treatment	Mean date of: Tassel	Silk	Harvest	No. of cobs (m^{-2})	Cob D.M. (gm^{-2})	Plant D.M (gm^{-2})
CL	23/7	19/8	17/10	13.0	347	1232
RL	8/8	30/8	27/10	11.8	280	1216
AL	17/8	15/9	3/11	6.9	41	1392
BS	15/8	4/9	31/10	7.9	76	1105

highly absorptive (BL) films accelerated and the cooler soil under the highly reflective (AL) film slowed the morphological development of the shoot meristem and resulted in faster and slower leaf appearance respectively. Subsequently, as the meristematic area was subjected to air temperature, between-treatment differences diminished.

The measurements of Fig. 4 show typical responses of leaf extension rate (R_e) to plant meristem temperature (T_p). Trends of R_e and T_p are similar, but leaf extension stopped when T_p fell below 10°C and it was resumed only when T_p again rose above 10°C. Regression analysis, assuming a linear relationship between all R_e and T_p measurements during the vegetative period, determined the lower temperature threshold (T_0) close to 9.5°C, in agreement with Friend (1966) and Blacklow's (1972) field results and disagreement with Watts' (1972) laboratory measurements. Indeed, when R_e was plotted against T_p the relation was, consistently, practically linear within a wide temperature range (above T_o) upto 28-29°C, where R_e levels off becoming maximum (Fig. 5). Watts (1972) for maize and Gallagher (1976) for barley found mostly linear but also exponential relations between R_e and T_p.

Early in the season the growing point temperature was governed by that of soil and R_e was correlated slightly more closely with the soil temperature at 2 cm depth ($r=0.93$) than with in-canopy air temperature ($r=0.91$). The elevation of the apical meristem above ground, as the seedlings grew, changed the significance of soil and air temperatures in determining growth rates. Dissection showed that meristem emerged above soil surface as soon as the sixth or seventh leaf appeared. Thus, after these leaf stages, canopy-air temperature was correlated with leaf extension slightly better ($r=0.98$) than soil temperature ($r=0.96$). Throughout the season, the highest correlation coefficients were obtained by relating R_e to T_p ($r=0.95$-0.98). This confirms the sensitivity of the stem apex region to temperature as reported by Watts (1972, 1973) for maize, Peacock (1975) for grasses and Gallagher (1976) for barley. Therefore, mulches affect growth as long as meristem temperature is influenced by the modified thermal regime.

5. Conclusions

Mulches modify the energy balance at the soil surface and consequently soil temperature. In early growth, soil temperatures determine meristem temperatures, at least until the sixth-seventh leaf stage, and, therefore, the rates of differentiation and growth.

Thus, seedling emergence and establishment are faster and more successful on warm mulched plots. than on bare soil plots.

Also, warming mulches accelerate whereas cooling mulches slow leaf appearance and growth. Leaf growth and meristem temperature are linearly related in the range 10°-29°C. Thus, even small temperature alterations due to mulches may produce significant crop performance differences.

Provided the drawbacks of mulches (cost, disposing difficulties and laying time) can be removed, use of the mulches potential for making yields more consistent and harvests earlier, could be made mainly in temperate climates. In hot climates cooling rather than warming mulches might perform better.

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